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# VISIBLE PYROTECHNIC FLARE SPECTROSCOPY USING VIDICONS

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The use of an optical multichannel analyzer (OMA) for obtaining the visible spectra of pyrotechnic flares is described. The configuration and design of the vidicon/spectrometer interface is presented. The visible spectrum of a standard Navy yellow flare, the Mk 118 Mod 0 Marine Smoke and Illumination Signal, obtained with the OMA is discussed. The advantages and disadvantages of the OMA system as a tool for flare spectroscopic measurements are discussed.

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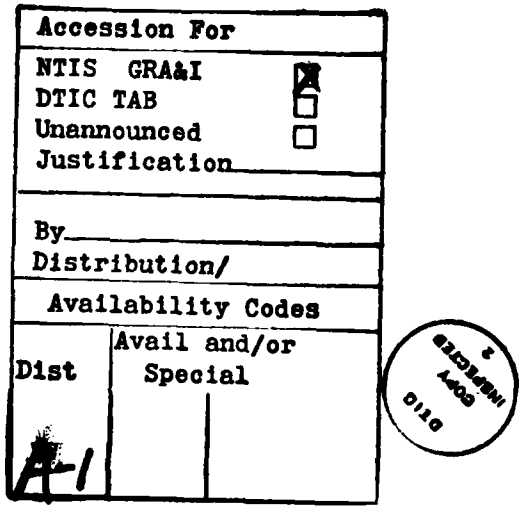
# PREFACE

This paper was presented at the 1982 Annual Fall Meeting of the Pyrotechnic and Explosive Applications Section of the American Defense Preparedness Association. The meeting was held 17-18 November 1982 at Tyndall Air Force Base, Florida.



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# INTRODUCTION

The measurement of emission spectra from burning pyrotechnic devices has, in the past, proven to be a costly and/or time-consuming process due to the problems associated with the transient nature of the pyrotechnic flame. Under the best circumstances intensity fluctuations of several percent occur during the course of a flare burn. These intensity fluctuations preclude the use of conventional scanning spectrometers for recording the emission spectra simply because a long time is required to complete the scan and there is no way to insure that the flare is emitting the same intensity at each wavelength point in the scan.

To overcome this problem at Crane, visible emission spectra are taken with a grating spectrograph. Operating with a photographic medium as the recording device a spectrograph measures all wavelengths simultaneously and provides an integrated intensity as a function of wavelength. This turns out to be an ideal solution to the problem of varying intensities. Unfortunately the data reduction associated with a photographic recording medium is very time-consuming. Many intensity calibration spectra must be obtained to accurately determine the

response of the spectrograph/detector system. The photographic medium must then be analyzed by a densitometer to determine optical density as a function of wavelength. This data must subsequently be manipulated by two separate computer programs to provide intensity versus wavelength for pyrotechnic flames. A normal amount of flare spectra (20-30 flares) requires approximately 30 hours to do the entire data reduction. It should also be pointed out that this number of hours will not be significantly less for a single flare.

Another, perhaps more satisfactory, solution to the varying intensities is the use of rapid scanning spectrometers or interferometers. This solution, however, requires a high initial equipment investment ($100,000 - $200,000), sophisticated maintenance to keep the instruments operative and a substantial amount of initial computer programming time to get the required results.

The purpose of this paper is to describe a fast, reasonably inexpensive, and, yet, effective method of obtaining visible emission spectra from burning pyrotechnic flames using a silicon-target vidicon and associated electronics.

## EXPERIMENTAL*

### Instrumentation

The instrumentation used in these experiments consisted of a Princeton Applied Research Corporation Model 1205 Optical Multichannel Analyzer (OMA) interfaced to a 0.25 meter Jarrell-Ash monochromator. The OMA consists of a detector head and a control console. The detector head is a 500 element silicon vidicon tube. The detector element size is 0.2 in X 0.5 in with each element being 0.001 in. The detector is sensitive from 350 nm - 1100 nm. The incident light signal modifies the charge states of the target in correspondance with the incident intensity. Each target element is then scanned every 32 msec. The output of the scanning electronics can be displayed in real-time or stored in one of two memory registers. The output can be accumlated into the memory registers for a preset number of cycles thus providing an integrated signal of the flare spectrum.

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*In order to specify procedures adequately, it has been necessary occasionally to identify commercial materials and equipment in this report. In no case does such identification imply recommendation or endorsement by the Navy, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

The 0.25 meter monochromator was modified for these experiments by removing the exit slit assembly and machining off the flange which was originally part of the cast monochromator housing. A holder for the OMA was constructed and the OMA was bolted to the side of the monochromator. The spectrum was then focused on the face of the OMA detector plate by adjusting the position of the entrance slit.

The standard monochromator grating was replaced with a research quality grating having a ruling of 150 grooves/mm and a 500 nm blaze angle. This grating gives a dispersion of 24.3 nm/mm which translates to 0.608 nm/target element. The grating was positioned to give a wavelength of 546 nm at the center of the detector. A 25 micron entrance slit was used on the monochromator. A Corning 0-52 filter was used to eliminate any overlapping second order radiation.

## Measurements

The flares burned in these experiments were the standard Mk 118 Mod 0 Marine Smoke and Illumination Signal. The flare composition is given in Table 1. The flares were burned at a distance of four meters from the spectrograph. No attempt was made to isolate any particular region in the flame.

The OMA was set to accumulate 170 scans into one memory register during the middle portion of the burn. The monochromator was then masked and an identical 170 scans were accumulated into the other memory register. The difference between the two registers was transferred to punched paper tape. At the start and completion of the experiment spectra of a 1000 watt quartz halogen lamp whose spectral radiant intensity was known were taken in exactly the same manner as the flare spectra. Wavelength calibration was done by using a mercury line source and a series of narrow band pass interference filters.

Table 1. Yellow Flare Composition

| | |
|---|---|
| Mg, Mil-M-382, Gran 18 | 30.3 |
| Potassium Perchlorate, MIL-P-217 | 21.0 |
| Barium Nitrate, MIL-B-162 | 20.0 |
| Sodium Oxalate, JAN-S-210 | 19.8 |
| Asphaltum, JAN-A-708 | 3.9 |
| Binder, MIL-STD-708 | 5.0 |

The punched paper tape data was processed on a Nova 1220 minicomputer. The response of the monochromator/filter/detector combination was calculated at each point by using the known values of the quartz halogen lamp spectral output and the measured values from the OMA system. Relative spectra were then calculated for the flare data using this system response curve.

## RESULTS

The relative radiant power spectrum obtained in these experiments is shown in Figure 1. Although not measured in these experiments the intensity of typical Mk 118 Mod 0 flares is 29000 cd and the burn time is 35 seconds for the flare weight of 140 grams. This spectrum is a single flare spectrum and is chosen as being representative of the group. Spectra of other flares taken under identical conditions are not significantly different.

## DISCUSSION

The spectrum shown in Figure 1 is a typical yellow flare spectrum and is in reasonable agreement with spectra obtained using high resolution grating spectrographs and photographic plates. The emission is primarily from the sodium lines centered at 590 nm. Molecular emission from BaCl and BaOH, from atomic potassium, and from the underlying grey body continuum contribute the remainder of the energy.

Obviously the very low resolution required when using the OMA system precludes the use of this particular grating/monochromator configuration for any molecular structure identification. Higher

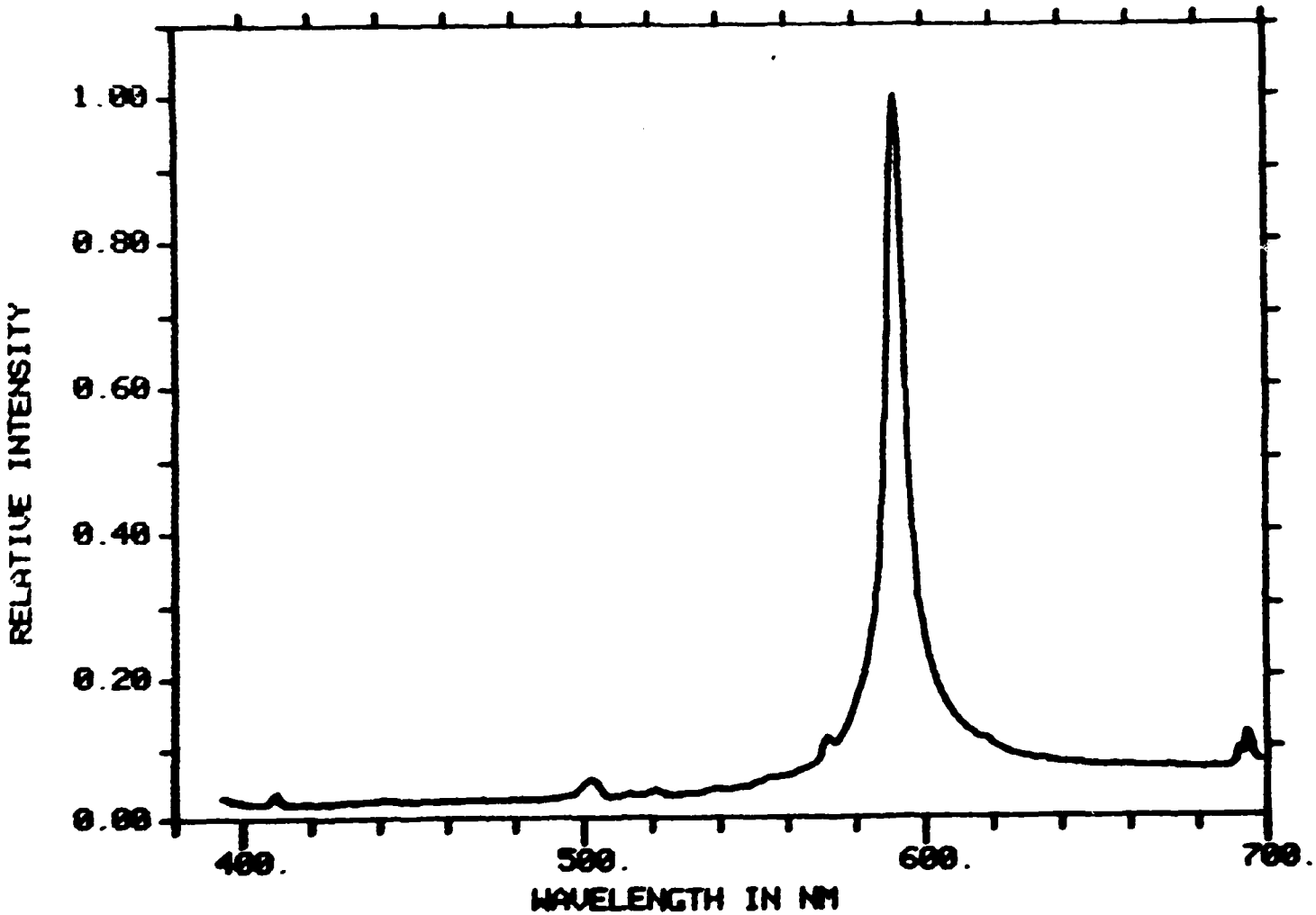


FIGURE 1. VISIBLE SPECTRUM OF MK 118 MARINE SMOKE AND ILLUMINATION SIGNAL

resolution can be obtained by using a more finely ruled grating but this must be done at the expense of spectral coverage available.

The major advantage of the OMA system is the low cost and short time required for data reduction. The spectrum shown in Figure 1 was obtained in approximately 10 minutes from the start of the experiment until the finished plot was obtained. This time will be reduced to less than five minutes per flare when appropriate interfacing is done to feed the digital output from the OMA directly into the computer and bypassing the punched paper tape. Thus twenty spectra can be processed in two hours rather than the thirty hours it now takes to do photographic spectra.

The data available from the low resolution OMA spectra is essentially unlimited depending on the amount of software one wishes to write. Flame temperatures can be obtained for black body type sources. Spectral tristimulus values can be applied to the data and the color (dominant wavelength and purity) of the flare can be determined more accurately than is possible with standard colorimeters. Absolute calibrations and appropriate integration can allow the calculation of luminous intensities.

## CONCLUSIONS

These experiments have shown that it is possible to use a low resolution monochromator and an optical multichannel analyzer to obtain emission spectra from pyrotechnic devices in the region from 350 nm - 1100 nm. The spectra can be obtained with significant savings in both time and money and provide much of the same data obtained by the more laborious photographic recording of the spectra from a conventional grating spectrograph. Appropriate software development will also allow the calculation of many other pieces of data important in the development of new and improved pyrotechnic devices.

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